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(54) Resistive heating control system and method that is functional over a wide supply voltage range

Steuersystem und -verfahren für mit einer innerhalb eines grossen Bereichs veränderlichen Versorgungsspannung arbeitenden Widerstandheizung

Système et méthode de commande pour un chauffage par résistance fonctionnant dans une large gamme de tension d'alimentation

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Description

Technical Field

This invention relates generally to power control systems and more particular to a method and apparatus to control the amount of power dissipation in a resistive heating element.

Background of the Invention

Many applications require that the equipment work over a wide range of alternating voltages. Within the United States, the common power line voltage can range from 110 to 240 VAC. If a particular piece of equipment is to function in the US and other markets, the equipment must allow for the different operating voltages. Most equipment has solved this problem by providing a user activated switch from which the user selects the proper input voltage. Outside of the obvious problem of selecting the wrong setting and possible damaging the equipment, a switch arrangement presents other problems. Generally a switch arrangement implies that a transformer is used. The switch selects the appropriate primary windings on the transformer. By requiring a transformer, weight and bulk are increased and efficiency is decreased. The transformer, because of its plurality of windings, also adds additional cost.

Some modern equipment uses universal power supplies. These universal power supplies automatically output the proper internal voltages used by the equipment independent to the input voltage. Of course, even the universal power supplies have a fixed range of input voltage they can accept. The primary disadvantage with the universal power supplies is their cost and reduced efficiency. Efficiency becomes a problem when trying to convert a significant amount of power.

In the art of electrophotographic printing, for example, the print media must pass through a fusing system. In the fuser, the print media is pressed between a pressure roller and a heated roller. By applying heat and pressure, the image on the print media is melted and thereby fused to the print media. While the fuser roller may be heated in any manner, a lamp placed inside the fuser roller is the most common method. While the printer electronics and paper handling components can be powered by a universal power supply, the bulb is generally selected for the appropriate line voltage. Therefore, either a transformer is used to switch select the proper voltage for the bulb or two separate fuser systems are used, each with a relatively tight voltage range. Thus, the printer could not be made truly universal in power requirements.

EP-A-496529 relates to a power control system for a cook top which is adaptable to a plurality of supply voltages. The control, in response to an input signal identifying the voltage to be applied, selects the control parameters from a look-up table associated with the identified voltage. The control means is operated in response to the input to select the control parameters from a look-up table associated with the identified voltage and on the basis of the look-up table, a control word is read out, the bit pattern of which establishes the power repetition rate or power switching rate for the load. The power pulse repetition rate is determined on the basis of one of the tables wherein the tables are selected on the basis of the voltage identifying signal. Dependent from the power selection, a predetermined number of cycles of the power signal is applied to the heating element. Power levels which are not user selectable are provided, wherein these levels are available to adjust the power applied to the heating unit to overdrive the heater unit when operating a transient heat up mode to rapidly heat the units to radiant temperature.

It is the object of the present invention to provide an apparatus and a method for regulating an amount of power a heating element consumes which brings the heating element rapidly up to the operating temperature and simultaneously prolongs the life of the heating element.

This object is achieved by the apparatus according to claim 1 and by the method according to claim 4.

Brief description of the Drawings

Figure 1 is a block diagram of one embodiment in accordance with the present invention;

Figure 2 shows a normal AC sinusoidal power signal

Figure 3 shows the modified AC power signal after power control to reduce the power by approximately two-thirds.

Figure 4 is a block diagram of an alternative embodiment in accordance with the present invention.

Figure 5 is a flow diagram of logical steps implemented in accordance with the present invention

Detailed Description of the Preferred Embodiments

The present invention pulse width modulates the incoming AC power to control the amount of power the heating element dissipates. This arrangement takes advantage of the understanding that the voltage rating associated with commonly available resistive incandescent heating lamps can be ignored over the common AC line voltage range, provided the power dissipation is controlled. Thus, operating a lamp rated at 120 volts and 750 watts at 210 volts with a 33% duty cycle still produces 750 watts. Operating such heating devices at higher voltages with controlled power dissipation appears to have no ill effect on the devices and may even be beneficial to the lamp.

Referring first to Figure 1, a first embodiment of the present invention is shown. Here, MICROPROCESSOR 10 supplies an on/off signal to CONTROL SYSTEM 11. CONTROL SYSTEM 11 in turn supplies the ap-

propriate control signal to ZERO-CROSSING SWITCH (ZCS) 12. As shown, CONTROL SYSTEM 11 must know the approximate line voltage. With this information, CONTROL SYSTEM 11 can then modulate the control signal to ZCS 12 to control the amount of power to HEATING ELEMENT 13. ZERO-CROSSING SWITCH 12 ensures that the power to HEATING ELEMENT 13 is switched during a zero crossing of the input AC voltage. As is understood in the art, such switching reduces the electrical noise generated. A detailed description of the function of CONTROL SYSTEM 11 is provided in a subsequent paragraph.

Referring next to Figures 2 and 3, a detailed description of the function of the present invention is given. Figure 2 shows a typical input AC power waveform, which is generally a sine wave. If the complete sine wave is applied to the heating element, then the power dissipation is a function of the voltage (V) of the input AC waveform and the resistance (R) of the heating element. Because heating elements' resistance (R) changes over time and temperature, actual resistance is a complex function. However, for simplification the following discussion uses a nominal steady state value of R. Thus if a given heating element is rated at P watts for V input voltage, it has a resistance R of:

$$R = \frac{V^2}{P} \qquad \text{eqn. 1}$$

By way of an example, use a heating element rated at 750 watts at 120 VAC, then:

$$R = \frac{V^2}{P} = \frac{120^2}{750} \approx 19.2\Omega \qquad \text{eqn. 2}$$

If the same amount of power is wanted with a voltage of 210 VAC, then:

$$R = \frac{V^2}{P} = \frac{210^2}{750} \approx 58.8\Omega \qquad \text{eqn. 3}$$

On the other hand, if the 120 VAC heating element was used with the 210 VAC source, then the amount of power dissipated would be:

$$P = \frac{V^2}{R} = \frac{210^2}{19.2} \approx 2290W! \qquad \text{eqn. 4}$$

It should be evident that the heating element would probably be destroyed or at least damaged if the wrong voltage were applied for any extended length of time. From equation 4, the ratio of desired power to actual power dissipation for the 120 VAC heating element with 210 VAC applied is approximately:

$$\frac{750}{2290} \approx \frac{1}{3} = 33\% \qquad \text{eqn. 5}$$

or:

$$\left(\frac{V_1}{V_2}\right)^2 = \left(\frac{120}{210}\right)^2 \approx 0.33 = 33\% \qquad \text{eqn. 6}$$

Thus, if the duty cycle of the 210 VAC is reduced to 33%, then the 120 VAC heating element will dissipate on average 750W.

In figure 3, line 20 shows a sine wave with a 33% duty cycle. Note, the dotted lines represent those portions of the sine wave that is not applied to the heating element. Below the sine wave is the control signal 21 used to modulate the sine wave. As stated above, the present invention uses a zero crossing switch to reduce electrical noise. With a zero crossing switch whenever the input sine wave crosses the zero voltage, the control signal is sampled. If the signal is high, then the switch is turned on for the next half cycle. If, on the other hand, the control is low, the switch is turned off for next half cycle. Therefore, when the control signal is high, the sine wave is applied to the heating element. Thus, by controlling the duty cycle of the control signal, the duty cycle of the applied voltage can also be controlled. In the present example, the control signal has a duty cycle (t1/t2) of approximately 33%.

As an alternative to using a ZCS, if the changes in the control signal are synchronized to zero crossing of the input power, a ZCS is not necessary. Such synchronization can easily be implemented by using a zero crossing detector to output a gating signal to gate the control signal. This synchronization could also be accomplished by detecting a zero crossing in the AC sense signal in real time and only toggling the control signal during those zero crossing times.

Continuing with the example, assuming that the waveform of figure 3 is applied to the heating element, then the heating element will dissipate 2290W for 33% of the time and 0W for 66% of the time for an average of 750W over time. As stated earlier, a heating element's resistance is a complex function. Through empirical testing it has been found that the resistance of the above heating element will increase slightly from the nominal value of 19.2.Ω Therefore, it may be necessary to increase the duty cycle to produce the proper amount of power.

As seen in figure 1, AC SENSE 14 receives the power source signal and generates a signal that identifies the input power voltage level. Depending on the particular embodiment, the signal may be proportional to the input voltage, or in the alternative, may simply represent that the input voltage is within a given range. From this information, the CONTROL SYSTEM 11 can determine the present voltage and necessary duty cycle to provide the desired heating power.

CONTROL SYSTEM 11 can be arranged such that the AC SENSE signal selects the proper duty cycle from a limited number of selections. In the alternative, the AC SENSE signal could allow an infinite number of possible duty cycles. One embodiment of CONTROL SYSTEM 11 might be accomplished by using multivibrators. Other embodiments of the CONTROL SYSTEM 11 might include using a counter circuit to divide a clock signal from the MICROPROCESSOR 10 by a known factor to generated the desired control signal. Other detailed implementations of the CONTROL SYSTEM 11 can be made by one skilled in the art. The particular embodiment of the CONTROL SYSTEM 11 is not important to the present invention, provided that the embodiment performs the desired function.

Figure 4 shows an alternative embodiment of the present invention. Here, MICROPROCESSOR 10 directly modulates the control signal to ZCS 12. This arrangement has several advantages. First, a reduced part count leading to higher efficiency and reliability and lower cost. Second, firmware in the MICROPROCESSOR 10 can easily include features such as soft start to prolong the life of HEATING ELEMENT 13 or rapid start to quickly bring the system up to operating temperature. With this arrangement, MICROPROCESSOR 10 can generate the modulation signal (21 of figure 3) directly. Additionally, with either arrangement of figure 1 or 4, the MICROPROCESSOR 10 can turn off and on the HEATING ELEMENT 13 as needed. As stated above, this allows the system to reduce power when heat is not needed.

Referring next to figure 5 where a logical flow diagram for MICROPROCESSOR 10 is shown. Once the master program of the system determines that the heater should be turned on, the steps of figure 5 are executed. Before the heater can be turned on, MICROPROCESSOR 10 must either first determine what the AC line voltage is 31 or make a first approximation. As stated above, MICROPROCESSOR 10 may either receive a signal that is proportional to the input voltage, or simply a finite number of discrete signals indicating that the voltage is within a given range. Independent of the sensing method, the duty cycle of the control signal must be determined 32. This step may be accomplished by having MICROPROCESSOR 10 actual calculating the duty cycle using equation 6 or in the alternative, a look-up table with pre-calculated duty cycles based on the input AC voltage could be used. A person skilled in the art could devise other methods of determining the duty cycle without undue experimentation.

After MICROPROCESSOR 10 has determined the duty cycle, the control signal with that duty cycle must be generated 33. As with step 32, step 33 can be implemented several ways. For example, MICROPROCESSOR 10 can be interrupted at regular intervals. During such intervals MICROPROCESSOR 10 determines if the control signal needs to be toggled and do so if needed. Another approach places the burden of counting and generating the signal in a hardware counter. Other arrangements are possible beyond the two described here. The description of these two are not meant to limit the step of 33 to only these two implementations.

While the control signal is generated, MICROPROCESSOR 10 should periodically recheck the AC voltage 34. If the voltage changes by a significant amount, the duty cycle may need to be re-calculated 32. MICROPROCESSOR 10 must also detect when the main system signals to turn the heater off 35 and do so. Other functions can be added to figure 5. For example, a temperature monitor used to signal MICROPROCESSOR 10 if the temperature of heater is within tolerances. Such a temperature sensing device placed near the HEATING ELEMENT 13, while not necessary for the operation of the present invention, may provide real-time information that the microprocessor can use to adjust the duty cycle for proper operating temperature. Information from the temperature sensing device may also indicate that the heating element is operating within certain safety constraints.

By using the already present microprocessor, pulse width, frequency and timing of the applied voltage can be optimized in real time. By such an arrangement, additional benefits such as soft-start, rapid warm-up, reduced flicker, and constant output can also be implemented.

As is understood in the art, a heating element is most likely to fail during the initial application of power to a cold element. The inrush current can he very high because the cold resistance of the heating element is much lower than the nominal operating resistance. A soft-start allows the heating element than the nominal operating resistance. A soft-start allows the heating element to slowly reach its operating temperature and nominal resistance. Thus, by slowing increasing the duty cycle of the control signal, the initial current inrush is controlled, thereby reducing the likelihood of premature failure of the heating element.

Similarly, once the heating element has reached operating resistance, the duty cycle can be increased above the nominal operating duty cycle for short periods. The increased duty cycle causes the heating element to output an increased amount of heat. By increasing the heat output of the heating element, the operating temperature can be reached faster. Assuming the thermal dynamics of the system are sufficient such that the operating temperature can be reached in a relatively short period of time, subjecting the heating element to the increased power dissipation for this short period of time will have no ill effect on the heating element. Thus, by temporarily increasing the duty cycle of the control signal, the heating system can rapidly reach its operating temperature.

As with any system, failures can occur. Should MICROPROCESSOR 10 fail and the control signal to ZCS 12 be in the high state, HEATING ELEMENT 13 may overheat thereby causing a potential safety hazard.

Thus some additional safety measures should be added. Some additions might include AC coupling the control signal to ZCS 12 such that if the signal is not periodically toggled, the signal to ZCS 12 becomes low thereby turning off ZCS 12. Other safety systems might include a thermal fuse or circuit breaker that disables power to the heater element if the temperature is above a preset level. It should be readily apparent that the present invention is compatible with many of these common safety systems. Numerous other safety circuits are possible.

In summary, this present invention takes advantage of the understanding that the voltage rating associated with commonly available resistive heating element can be ignored over the common AC line voltage range, provided the power dissipation is controlled. Prior to the present invention, the MICROPROCESSOR 11 directly controlled the ZERO-CROSSING SWITCH (ZCS) 12 with no knowledge of the input AC voltage. With the present invention, CONTROL SYSTEM 11 is placed between MICROPROCESSOR 10 and ZCS 12 or MICROPROCESSOR 10 is provided with information about the input AC voltage. Based on the detected AC voltage, the control signal to ZCS 12 is modulated such that the heater element dissipates the same amount of heat independent of the AC line voltage. This enables a heating element designed to operate at a specific AC voltage to operate at greater voltages while still dissipating the correct amount of power.

Claims

1. An apparatus for regulating an amount of power an electrical heating element (13) consumes, said electrical heating element (13) being designed to operate at a rated voltage with a nominal operating resistance, said apparatus comprising of:

    a main power supply generating a periodically varying output voltage, said rated voltage being less than said output voltage;

    a zero crossing detector (12) for detecting zero crossings of said output voltage where said zero crossings occur between positive and negative half cycles of said output voltage;

    signal generator means (10,11) for generating a control signal (21) having a nominal operating duty cycle, said control signal having a first state (t_2) and a second state (t_1), a ratio of the duration of said first state and the duration of said second state being a function of said rated voltage and said output voltage, said nominal operating duty cycle being a function of said ratio, said signal generator means changing said control signal between said first state (t_2) and said second state (t_1) only when said zero crossing detector (12) detects a zero crossing,

    wherein during a predetermined time after the operating resistance of the electrical heating element (13) is reached the signal generator means (10,11) increases the duty cycle above the nominal operation duty cycle until the operating temperature of the electrical heating element (13) is reached, and

    wherein the signal generator means (10,11) generates the control signal having the nominal operating duty cycle when the operating temperature of the electrical heating element (13) is reached; and

    a switch (12) arranged to receive said control signal from said signal generator means (10,11), said switch connecting said output voltage from said main power supply to said electrical heating element (13) when said control signal (21) is in said first state (t_2);

    characterized in that
    during an initial heating phase of the electrical heating element (13) said signal generator means (10,11) slowly increases the duty cycle until the nominal operating resistance of the electrical heating element (13) is reached.

2. An apparatus as claimed in claim 1, wherein said signal generator means (10,11) further comprises voltage sensing means (14) for sensing said output voltage and generating a voltage level signal that is proportional to said output voltage, said signal generator means (10,11) using said voltage level signal to determine said ratio.

3. An apparatus as claimed in claim 2, wherein said signal generator means (10,11) is a microcomputer means (10) arranged to receive said voltage level signal generated by said sensing means (14), said microcomputer means (10) determines said ratio and based on said ratio generates said control signal.

4. A method for regulating an amount of power an electrical heating element (13) consumes, said electrical heating element (13) being designed to operate at a rated voltage with a nominal operating resistance, said method comprising the steps of:

    receiving (31) a periodically varying output voltage from a main power supply, said rated voltage being less than said output voltage;

    generating (33) a control signal (21) having a

nominal operating duty cycle, said control signal having a first state (t_2) and a second state (t_1), a ratio of the duration of said first state and the duration of said second state being a function of said rated voltage and said output voltage, said nominal operating duty cycle of said control signal being a function of said ratio;

during a predetermined time after the operating resistance of the electrical heating element (13) is reached increasing the duty cycle above the nominal operating duty cycle until the operating temperature of the electrical heating element (13) is reached;

detecting zero crossings of said output voltage where said zero crossings occur between positive and negative half cycles of said output voltages; and

connecting said main power supply to said electrical heating element (13) when said control signal is in said first state (t_2) and said step of detecting detects a zero crossing, said step of connecting disconnects said main power supply from said electrical heating element (13) when said control signal is in said second state (t_1) and said step of detecting detects a zero crossing;

characterized by the following step:

during an initial heating phase of the electrical heating element (13) slowly increasing the nominal duty cycle until the operating resistance of the electrical heating element (13) is reached.

5. A method as claimed in claim 4, wherein said duty cycle is less than or equal to one.

Patentansprüche

1. Eine Vorrichtung zum Regulieren einer Leistungsmenge, die ein elektrisches Heizelement (13) verbraucht, wobei das elektrische Heizelement (13) entworfen ist, um bei einer Nennspannung mit einem nominellen Betriebswiderstandswert zu arbeiten, wobei die Vorrichtung folgende Merkmale aufweist:

eine Hauptleistungsversorgung, die eine sich periodisch ändernde Ausgangsspannung erzeugt, wobei die Nennspannung niedriger als die Ausgangsspannung ist;

eine Nulldurchgangserfassungseinrichtung (12) zum Erfassen von Nulldurchgängen der Ausgangsspannung, wobei die Nulldurchgänge zwischen einem positiven und einem negativen Halbzyklus der Ausgangsspannung auftreten;

eine Signalgeneratoreinrichtung (10, 11) zum Erzeugen eines Steuersignals (21) mit einem nominellen Betriebsschaltverhältnis, wobei das Steuersignal einen ersten Zustand (t_2) und einen zweiten Zustand (t_1) aufweist, wobei das Verhältnis der Dauer des ersten Zustandes zu der Dauer des zweiten Zustandes eine Funktion der Nennspannung und der Ausgangsspannung ist, wobei das nominelle Betriebsschaltverhältnis eine Funktion des Verhältnisses ist, wobei die Signalgeneratoreinrichtung das Steuersignal zwischen dem ersten Zustand (t_2) und dem zweiten Zustand (t_1) lediglich dann ändert, wenn die Nulldurchgang-Erfassungseinrichtung (12) einen Nulldurchgang erfaßt;

wobei während einer vorbestimmten Zeitdauer, nachdem der Betriebswiderstandswert des elektrischen Heizelements (13) erreicht ist, die Signalgeneratoreinrichtung (10, 11) das Schaltverhältnis über das nominelle Betriebsschaltverhältnis erhöht, bis die Betriebstemperatur des elektrischen Heizelements (13) erreicht ist, und

wobei die Signalgeneratoreinrichtung (10, 11) das Steuersignal mit dem nomimellen Betriebsschaltverhältnis erzeugt, wenn die Betriebstemperatur des elektrischen Heizelements (13) erreicht ist; und

einen Schalter (12), der angeordnet ist, um das Steuersignal von der Signalgeneratoreinrichtung (10, 11) zu empfangen, wobei der Schalter die Ausgangsspannung von der Hauptleistungsversorgung mit dem elektrischen Heizelement (13) verbindet, wenn sich das Steuersignal (21) in dem ersten Zustand (t_2) befindet;

dadurch gekennzeichnet, daß

die Signalgeneratoreinrichtung (10, 11) das Schaltverhältnis während einer anfänglichen Erwärmungsphase des elektrischen Heizelements (13) langsam erhöht, bis der nominelle Betriebswiderstandswert des elektrischen Heizelements (13) erreicht ist.

2. Eine Vorrichtung gemäß Anspruch 1, bei der die Signalgeneratoreinrichtung (10, 11) ferner eine Spannungserfassungseinrichtung (14) zum Erfassen der Ausgangsspannung und zum Erzeugen eines Spannungspegelsignals aufweist, das zu der Ausgangsspannung proportional ist, wobei die Signalgeneratoreinrichtung (10, 11) das Spannungspe-

gelsignal verwendet, um das Verhältnis zu bestimmen.

3. Eine Vorrichtung gemäß Anspruch 2, bei der die Signalgeneratoreinrichtung (10, 11) eine Mikrocomputereinrichtung (10) ist, die angeordnet ist, um das Spannungspegelsignal zu empfangen, das von der Erfassungseinrichtung (14) erzeugt wird, wobei die Mikrocomputereinrichtung (10) das Verhältnis bestimmt und basierend auf dem Verhältnis das Steuersignal erzeugt.

4. Ein Verfahren zum Regulieren einer Leistungsmenge, die ein elektrisches Heizelement (13) verbraucht, wobei das elektrische Heizelement (13) entworfen ist, um bei einer Nennspannung mit einem nominellen Betriebswiderstandswert zu arbeiten, wobei das Verfahren folgende Schritte aufweist:

   Empfangen (31) einer sich periodisch ändernden Ausgangsspannung von einer Hauptleistungsversorgung, wobei die Nennspannung niedriger als die Ausgangsspannung ist;

   Erzeugen (33) eines Steuersignals (21) mit einem nominellen Betriebsschaltverhältnisses, wobei das Steuersignal einen ersten Zustand (t_2) und einen zweiten Zustand (t_1) aufweist, wobei ein Verhältnis der Dauer des ersten Zustands zu der Dauer des zweiten Zustands eine Funktion der Nennspannung und der Ausgangsspannung ist, wobei das nominelle Betriebsschaltverhältnis des Steuersignals eine Funktion des Verhältnisses ist;

   während einer vorbestimmten Zeitdauer, nachdem der Betriebswiderstandswert des elektrischen Heizelements (13) erreicht ist, Erhöhen des Schaltverhältnisses über das nominelle Betriebsschaltverhältnis, bis die Betriebstemperatur des elektrischen Heizelements (13) erreicht ist;

   Erfassen von Nulldurchgängen der Ausgangsspannung, wobei die Nulldurchgänge zwischen einem positiven und einem negativen Halbzyklus der Ausgangsspannungen auftreten; und

   Verbinden der Hauptleistungsversorgung mit dem elektrischen Heizelement (13), wenn sich das Steuersignal in dem ersten Zustand (t_2) befindet und der Schritt des Erfassens einen Nulldurchgang erfaßt, wobei der Schritt des Verbindens die Hauptleistungsversorgung von dem elektrischen Heizelement (13) trennt, wenn sich das Steuersignal in dem zweiten Zustand (t_1) befindet und der Schritt des Erfassens einen Nulldurchgang erfaßt;

   gekennzeichnet durch folgenden Schritt:
   langsames Erhöhen des nominellen Schaltverhältnisses während einer anfänglichen Erwärmungsphase des elektrischen Heizelements (13), bis der Betriebswiderstandswert des elektrischen Heizelements (13) erreicht ist.

5. Ein Verfahren gemäß Anspruch 4, bei dem das Schaltverhältnis kleiner oder gleich 1 ist.

Revendications

1. Appareil pour réguler une quantité d'énergie qu'un élément de chauffage électrique (13) consomme, ledit élément de chauffage électrique (13) étant conçu pour fonctionner à une tension nominale avec une résistance de fonctionnement nominale, ledit appareil se composant:

   - d'une alimentation en énergie principale créant une tension de sortie variant périodiquement, ladite tension nominale étant inférieure à ladite tension de sortie;
   - d'un détecteur de passage par zéro (12) pour détecter les passages par zéro de ladite tension de sortie où lesdits passages par zéro apparaissent entre des demi-périodes positives et négatives de ladite tension de sortie;
   - de moyens générateurs de signaux (10, 11) pour créer un signal de commande (21) ayant un rapport cyclique de fonctionnement nominal, ledit signal de commande ayant un premier état (t_2) et un deuxième état (t_1), un rapport de la durée dudit premier état et de la durée dudit deuxième état étant une fonction de ladite tension nominale et de ladite tension de sortie, ledit rapport cyclique de fonctionnement nominal étant une fonction dudit rapport, ledit moyen générateur de signaux changeant ledit signal de commande entre ledit premier état (t_2) et ledit deuxième état (t_1) seulement quand ledit détecteur de passage par zéro (12) détecte un passage par zéro,
   dans lequel pendant une durée prédéterminée, après avoir atteint la résistance de fonctionnement de l'élément de chauffage électrique (13), les moyens générateurs de signaux (10, 11) augmentent le rapport cyclique au-dessus du rapport cyclique de fonctionnement jusqu'à ce que la température de fonctionnement de l'élément de chauffage électrique (13) soit atteinte, et
   dans lequel les moyens générateurs de signaux (10, 11) créent le signal de commande ayant le rapport cyclique fonctionnent nominal

quand la température de fonctionnement de l'élément de chauffage électrique (13) est atteinte; et

- d'un commutateur (12) conçu pour recevoir ledit signal de commande provenant desdits moyens générateurs de signaux (10, 11), ledit commutateur connectant ladite tension de sortie de ladite alimentation principale audit élément de chauffage électrique (13) quand ledit signal de commande (21) est dans ledit premier état (t_2);

caractérisé en ce que
pendant une phase de chauffage initiale de l'élément de chauffage électrique (13), lesdits moyens générateurs de signaux (10, 11) augmentent lentement le rapport cyclique jusqu'à ce que la résistance de fonctionnement nominale de l'élément de chauffage électrique (13) soit atteinte.

2. Appareil selon la revendication 1, dans lequel lesdits moyens générateurs de signaux (10, 11) comprennent de plus un moyen de détection de la tension (14) pour détecter ladite tension de sortie et créer un signal de valeur de tension qui est proportionnel à ladite tension de sortie, lesdits moyens générateurs de signaux (10, 11) utilisant ledit signal de valeur de tension pour déterminer ledit rapport.

3. Appareil selon la revendication 2, dans lequel lesdits moyens générateurs de signaux (10, 11) sont un moyen de microordinateur (10) conçu pour recevoir ledit signal de valeur de tension créé par ledit moyen de détection (14), ledit moyen de microordinateur (10) détermine ledit rapport et, en fonction dudit rapport, crée ledit signal de commande.

4. Procédé pour réguler une quantité d'énergie qu'un élément de chauffage électrique (13) consomme, ledit élément de chauffage électrique (13) étant conçu pour fonctionner à une tension nominale avec une résistance de fonctionnement nominale, ledit procédé comprenant les étapes consistant:

   - à recevoir (31) une tension de sortie variant périodiquement d'une alimentation principale, ladite tension nominale étant inférieure à ladite tension de sortie;
   - à créer (33) un signal de commande (21) ayant un rapport cyclique de fonctionnement nominal, ledit signal de commande ayant un premier état (t_2) et un deuxième état (t_1), un rapport de la durée dudit premier état et de la durée dudit deuxième état étant une fonction de ladite tension nominale et de ladite tension de sortie, ledit rapport cyclique de fonctionnement nominal dudit signal de commande étant une fonction dudit rapport;
   - pendant une durée prédéterminée, après avoir atteint la résistance de fonctionnement de l'élément de chauffage électrique (13), à augmenter le rapport cyclique au-dessus du rapport cyclique de fonctionnement nominal jusqu'à ce que la température de fonctionnement de l'élément de chauffage électrique (13) soit atteinte;
   - à détecter les passages par zéro de ladite tension de sortie où lesdits passages par zéro apparaissent entre des demi-périodes positives et négatives desdites tensions de sortie; et
   - à connecter ladite alimentation principale audit élément de chauffage électrique (13) quand ledit signal de commande est dans ledit premier état (t_2) et ladite étape de détection détecte un passage par zéro, ladite étape de connexion déconnecte ladite alimentation principale dudit élément de chauffage électrique (13) quand ledit signal de commande est dans ledit deuxième état (t_1) et ladite étape de détection détecte un passage par zéro;

   caractérisé par l'étape suivante consistant:

   - pendant une phase de chauffage initiale de l'élément de chauffage électrique (13), à augmenter lentement le rapport cyclique de fonctionnement nominal jusqu'à atteindre la résistance de fonctionnement de l'élément de chauffage électrique (13).

5. Procédé selon la revendication 4, dans lequel ledit rapport cyclique est inférieur ou égal à un.

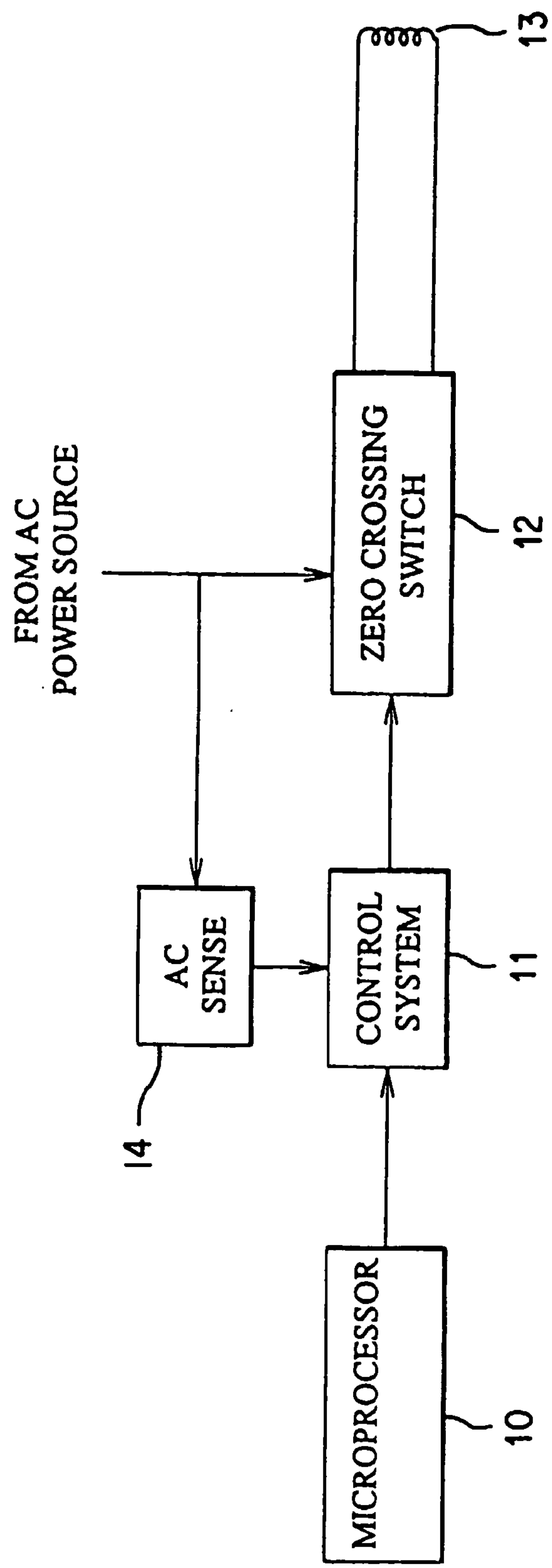
FROM AC
POWER SOURCE
ZERO CROSSING
SWITCH
12
13
AC
SENSE
14
CONTROL
SYSTEM
11
MICROPROCESSOR
10

FIG. 1

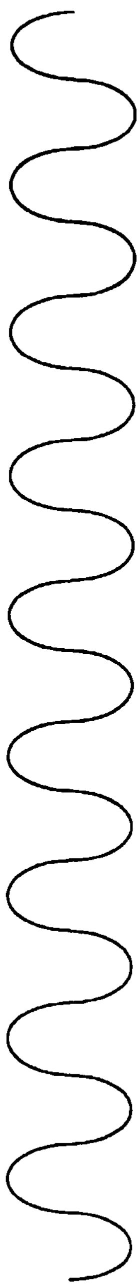

FIG. 2

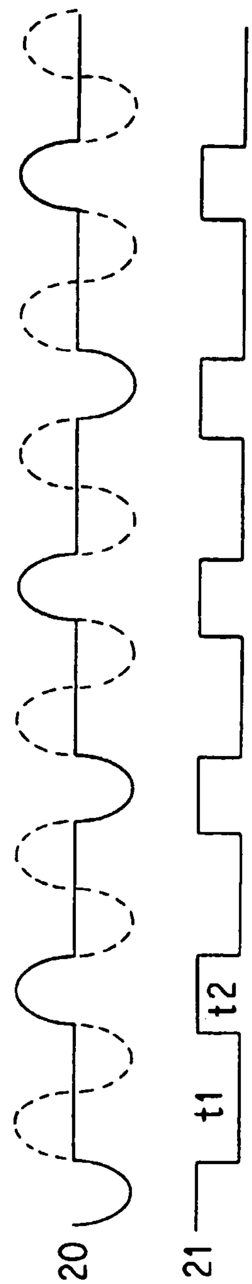

FIG. 3

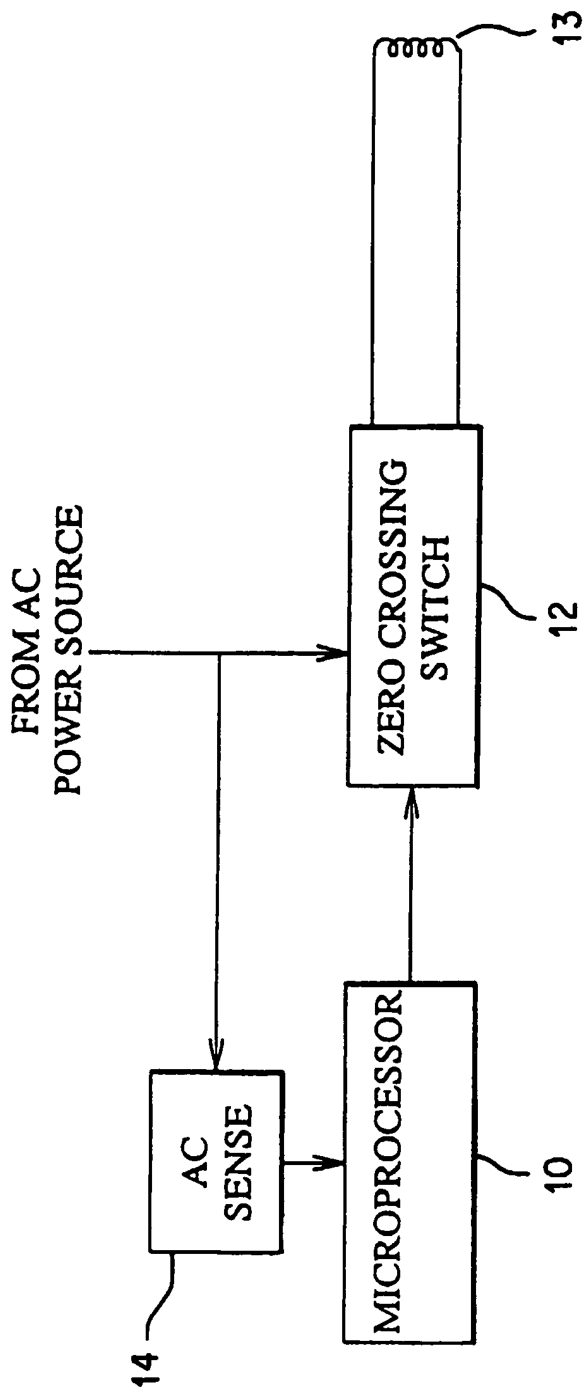
FROM AC
POWER SOURCE
ZERO CROSSING
SWITCH
MICROPROCESSOR
AC
SENSE
10
12
13
14

FIG. 4

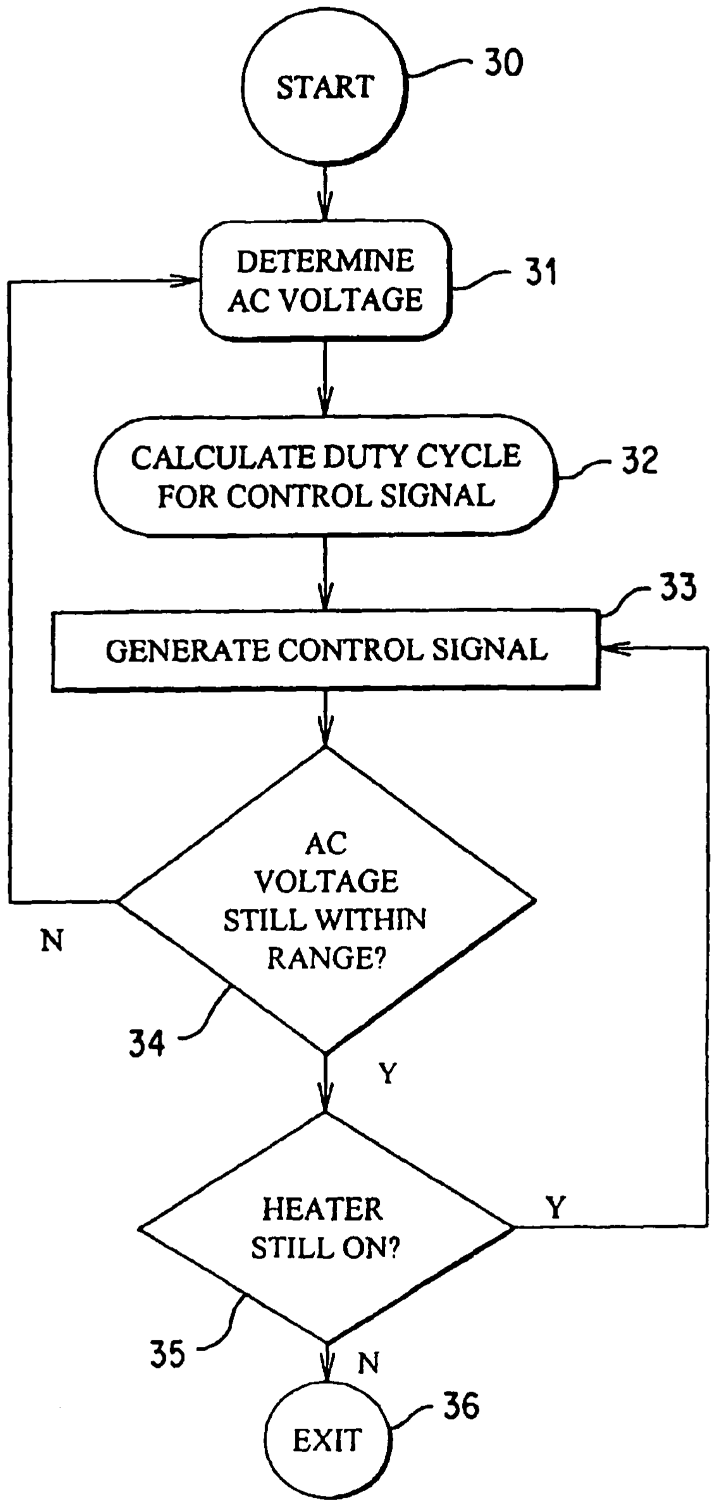
START
30
DETERMINE
AC VOLTAGE
31
CALCULATE DUTY CYCLE
FOR CONTROL SIGNAL
32
33
GENERATE CONTROL SIGNAL
AC
VOLTAGE
STILL WITHIN
RANGE?
N
34
Y
HEATER
STILL ON?
Y
35
N
EXIT
36

FIG. 5